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EXPERIMENTS WITH POLARIZED PROTON BEAM AT SATURNE II

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Abstract - A review of experiments using the polarized proton beam from SATURNE II is given. Measurements of the p-p analyzing power, total cross section differences with polarized beam and target, spin correlation parameters and of complete experiments including measurements of recoil polarizations are presented. In addition are given results of scattering experiments of polarized protons on a carbon target.

The very successful efforts of the LABORATOIRE NATIONAL SATURNE have resulted in a considerable improvement of the acceleration and the extraction of the polarized proton and deuteron beams at variable energies. The typical proton beam polarization is actually of 90% below 0.94 GeV ($\gamma G = \nu G$) and of 83% up to the highest energies of SATURNE II. The deuteron beam is polarized to more than 96%, which corresponds to $\sim 65\%$ of the deuteron vector polarization and of $\sim 60\%$ of neutron and proton polarization in the deuteron.

The present review discusses mostly nucleon-nucleon scattering experiments. Experiments with polarized deuteron beam are described in other contributions to this conference.

1) - The radiography experimental equipment was used by a group of DPhN/ME, CEN-Saclay to measure p-p elastic differential cross sections and analyzing powers between 600 MeV and 1 GeV in the angular region $16^\circ - 42^\circ$ lab. The polarized proton beam was scattered on a CH$_2$ target, positioned close to two proportional multi-wire chambers of $1\ m^2$. The trajectories of both scattered and recoil protons were recorded. The online analysis system allowed to select elastic events. The extracted beam energy was changed in steps of 50 MeV and was degraded by absorbers in steps of 10 MeV. The energy resolution of the apparatus was 3-7 MeV and the angular resolution $\sim 1^\circ$ lab. The aim of this experiment was to measure the energy dependences of $d\sigma/d\Omega$ and $A_{pp00}$ in the region of a possible dibaryonic resonance. The results show smooth energy dependences at fixed scattering angles. Several thousands of data points will soon be available.

2) - The experiments described in the following were carried out by the Nucleon-Nucleon group (collaboration of DPhPE, DPhN/ME and LNS, CEN-Saclay, University of Geneva, INFN, Trieste and LAPP, Annecy).

2a) - A new method was investigated in order to determine the polarization of proton beams accelerated to high energies by measurements after deceleration to low energies where simple and precise techniques can be used based on the large and well known analyzing power of p-p scattering. The polarized proton beam was accelerated to 520 MeV and its polarization was measured by extracting the beam onto the N-N beam line pola-
rimeter. The beam was then accelerated to 800 MeV, decelerated to 520 MeV and again extracted. The loss in polarization is due to crossing twice the depolarizing resonance \( y_G = 3 \) at 631 MeV with adiabatic spin flip, once during acceleration and once during deceleration. The depolarization was intentionally increased by partially correcting the resonance, thus making the adiabatic flip less complete. The correction was introduced either at the rise or at the descent. The final polarization was the same in both cases showing that the depolarization, as expected, was the same during acceleration and deceleration. Another measurement was performed between 0.88 GeV and 1.2 GeV crossing successively two intrinsic resonances \( y_G = v_0 \) at \( \sim 0.9 \) GeV and \( y_G = 4 \) at 1.145 GeV. Here the polarization at 1.2 GeV was measured directly and was compared to the value calculated from the measurements at 0.88 GeV before accelerating to 1.2 GeV and after decelerating from 1.2 GeV, assuming symmetric depolarization. The measured and the calculated values agree within \( \Delta P_B = 0.03 \) at \( P_B = 0.75 \).

Several other results were obtained as by products of the beam polarization measurements with the same polarimeter.

2b) - With this polarimeter, one measures the asymmetries in proton scattering on \( \text{CH}_2 \) and C targets, detecting scattered and recoil protons in coincidence. The ratio of analyzing powers for quasielastic p-p scattering in carbon \( A_{pp}(C) \) and for elastic p-p scattering on free target protons \( A_{pm}(p-p) \) was determined at an angle close to maximum of \( A_{pm}(p-p) \) at different energies between 0.52 to 2.8 GeV (1). The measured ratio is equal to the ratio of asymmetries \( \epsilon_{pp}(C) / \epsilon_{pp} \) (independent on the beam polarization) and is shown in Fig. 1. It is increasing by about 20% from \( T = 0.52 \) GeV to \( \sim 0.85 \) GeV where it reaches \( \sim 0.65 \) and then is decreasing by about 30% with the energy increasing up to 2.8 GeV. Simple models for quasielastic scattering in nuclei predict monotonous increase with increasing energy, approaching asymptotically a constant value smaller than one. The observed strong difference in the energy dependence between \( A_{pm}(p-p) \) and \( A_{pp}(C) \) may be an indication for a specific multiple scattering mechanism in nuclei.

\[ \text{Fig. 1 - Results for the ratio } \frac{\epsilon_{pp}(C)}{\epsilon_{pp}} = \frac{A_{pp}(C)}{A_{pp}} \text{ as a function of the kinetic energy.} \]

2c) - Another experiment measuring the analyzing power of the "inclusive reaction pC } \rightarrow p'X" from 0.52 to 2.8 GeV was also deduced from the beam polarization measurements (2).

The emission of charged particles \( p' \) in pC interactions results from several different reactions: Elastic or inelastic coherent scattering off the nucleus and elastic or inelastic scattering on quasi-free protons or neutrons. The polarized beam asymmetry for the reaction pC } \rightarrow p'X" involving all of these channels was measured at several angles between 11.5° and 74° lab. at 20 energies.

The results are shown in Fig. 2. They are useful for designing carbon analysers for high energy experiments.

\[ \text{Fig. 2 - The analyzing power for inclusive p-C scattering as a function of the beam kinetic energy.} \]
The total cross section difference $\Delta \sigma_L(pp)$ with both beam and target longitudinally polarized has been measured for 11 energies ranging from 0.52 to 2.8 GeV(3), in order to confirm the previously observed structure at $= 0.76$ GeV, to improve the knowledge of this parameter up to 2.8 GeV and to contribute to a data base for an amplitude analysis. The experiment was completed in November 1983, it was the continuation of the previous measurements of $\Delta \sigma_L(pp)$ at SIN(4).

A movable magnet system provides a longitudinally polarized beam incident on the polarized target with the same direction at all energies. The vertical beam polarization is first rotated into the horizontal plane by a solenoid, and then rotated into the longitudinal direction by a bending magnet. The bending angles for 90° precession with respect to the momentum are $= 32°$ and 12.7° at 0.52 GeV and at 2.8 GeV, respectively. The absence of transverse polarization components is checked with the second polarimeter of the N-N beam line measuring both the up-down and the left-right asymmetries.

The polarized proton frozen spin target (PPT) is made of doped butanol or, for most of the measurements, pentanol in a 3~e-4~e dilution refrigerator. It is polarized to $|F_T| = 0.8$ at 0.2 K in the homogenous field of a 2.5 Tesla superconducting solenoid. During the measurements this solenoid is removed and the polarization is held at 50 mK in a 0.3 Tesla magnetic field parallel to the incident beam. The relaxation time was measured to be one month. The target polarization was reversed not as usual by destroying the polarization and then repolarizing with the opposite sign, but by rotating the holding field into the opposite direction without any measurable loss of polarization. This method is considerably faster. For either sign of the holding field the beam polarization reversal yields an independent measurement. The two results always agree within statistics. Furthermore, at one of the energies $\Delta \sigma_L$ had been measured previously with target sign reversal by repolarization. Both methods give identical results. The spin rotation method, possible only in the frozen spin mode, introduced no measurable systematic error because the beam is parallel to the field, both the detectors and the field have axial symmetry around a common axis, and the field integral downstream of the target is small.

The electronic acquisition system is well protected against beam rate effects(3). As a result, when varying the beam intensity from $10^4$ to $5 \times 10^5$ particles per sec., the rate effect in the cross section measurement was less than $\pm 0.2$ mb.

The transmission detector, at about 1 m from the target, was composed of a central counter and a novel type of coded detector described in refs (3,4). An assembly of scintillation counters encodes the radial position in the GRAY code. The analysis uses 11 bins, from $2.5°$ to $7°$ lab. at all energies.

The results are shown in Fig. 3. Below 0.8 GeV the Saclay data together with those...
previously obtained at Argonne ZGS, SIN and LAMPF definitely establish the energy dependence of $\Delta \Omega_2$ with a difference of $(8.0 \pm 0.5)$ mb between 0.52 GeV and 0.76 GeV. The minimum at ~0.55 GeV can be explained by a possible $^1D_2$ resonance but the Saclay-Geneva PSA shows that the maximum at 0.76 GeV, attributed in several papers to a $^3P_2$ resonance, may have a rather non-resonant character. At lowest energy there is a good agreement with the results from SIN and LAMPF whereas the results from TRIUMF are systematically higher. Above 0.8 GeV the Saclay data are in fair agreement with those from Argonne ZGS and show no indication for either similar strong structures in the energy dependence, at least up to 1.8 GeV, or for a change of sign below 2.8 GeV.

Note that Saclay data together with those of SIN, measured with the same transmission system, represent more than one half of all existing spin dependent total cross section measurements.

2e) The angular distributions of the spin correlation parameter $A_{Ookk}(p-p)$ (longitudinally polarized beam and target) were measured at 0.84, 0.88, 0.94, 1.0 and 1.1 GeV. The data were completed by the measurement of $A_{Onnn}(p-p)$ at 0.88 GeV. Almost final data of $A_{Ookk}$ at 0.84 GeV are shown in Fig. 4. They are compared with two sets of data from Argonne, with recent LAMPF results and with the predictions of the Saclay-Geneva PSA at 800 MeV. This experiment is described in a separate contribution to this conference.

2f) The experimental equipment of the N-N group was completed in November 1983 as shown in Fig. 5. It consists of the recoil polarimeter and spectrometer arms in coincidence. The angular acceptance of both arms is $\pm 11^\circ$ and $\pm 5^\circ$ in horizontal and vertical planes, respectively. The trigger is the four-fold coincidence TD.TG, $\Sigma_3H3(1)\Sigma_4H12(1)$ where TD and TG are single counters and $\Sigma_3H3(1)$ and $\Sigma_4H12(1)$ are the logic sums of hodoscope counters. The trigger started the acquisition of wire chambers C1 to C14. The double scattering events are selected on-line using a microprocessor.

The aim of this experiment is to measure a complete set of experimental quantities in order to determine the p-p scattering matrix. The optimized set consists of four measurements which yield 3 parameters with 3 indices, two spin correlations, four Wolfenstein parameters and the analyzing power. The differential cross sections are assumed to be known from existing experiments.

The complete set of experiments was recently measured at 0.84, 0.88, 0.94, 1.0 and 1.1 GeV in the angular region $45^\circ$ to $90^\circ$ CM. The statistics allow to obtain an absolute error of 0.02-0.03 in two days of data taking at a given energy. The data analysis is in progress.

The future program of the N-N group is to measure complete sets of parameters up to the highest energy of SATURNE II, followed by similar measurements in n-p scattering in collaboration with the University of Geneva.
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